



Sustainment of SSM/I and AMSU CDRs

Frank J. Wentz and Carl Mears
Remote Sensing Systems
707-545-2904

frank.wentz@remss.com, mears@remss.com

Outline

- Project Description
- Production Approach
- QA Approach
- Applications
- Schedule & Issues

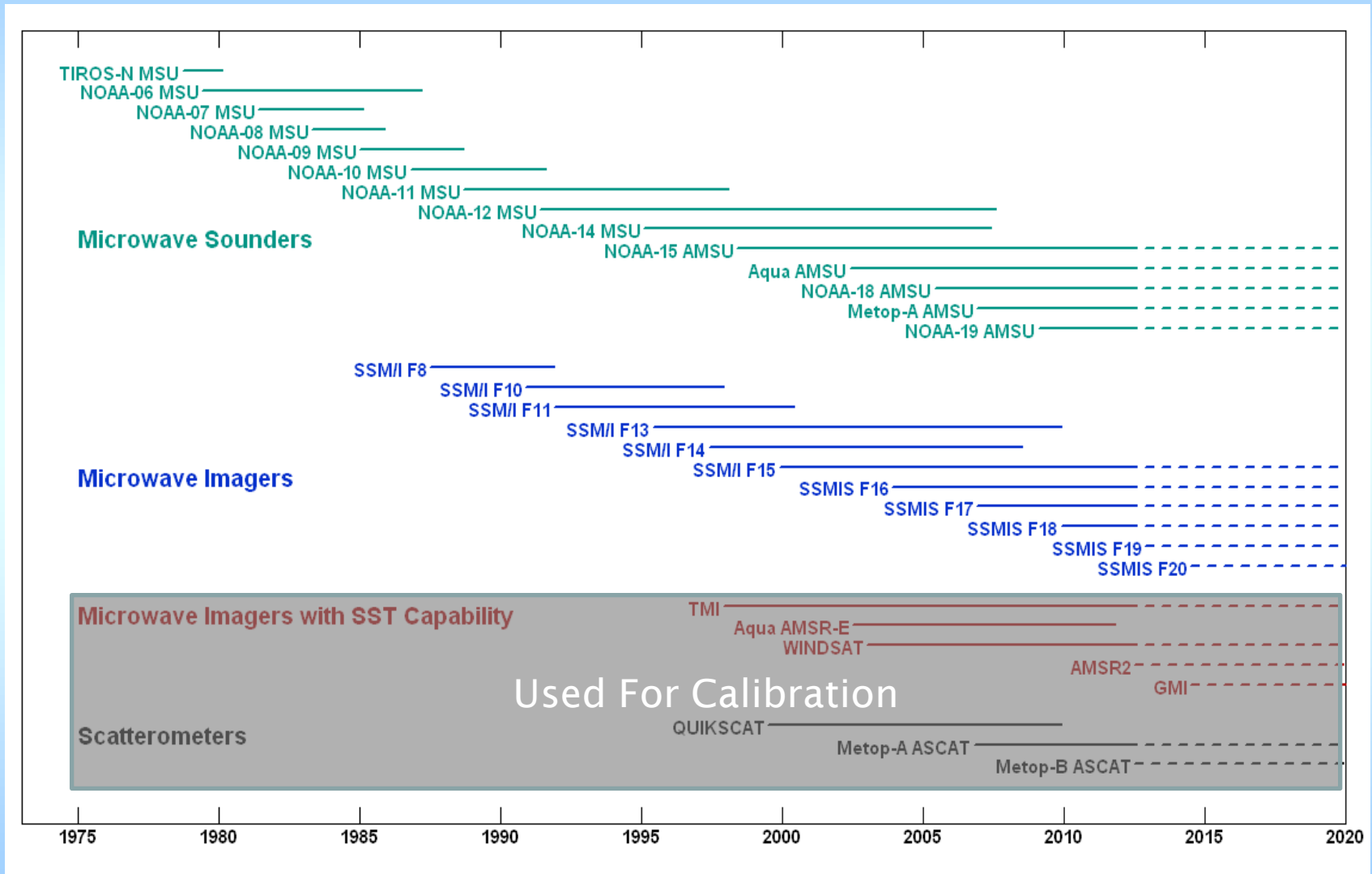
Project Description

MSU/AMSU Air Temperatures and SSM/I, SSM/IS Brightness Temperatures

CDR(s) (Validated Outputs)	Period of Record	Spatial Resolution; Projection information	Time Step	Data format	Inputs	Uncertainty Estimates (in percent or error)	Collateral Products (unofficial and/or unvalidated)
Atmospheric Temperature from MSU/AMSU Low Tropo. Mid Tropo. Tot Tropo. Low Strato.	1978- present	Global Monthly Maps at 2.5 degree resolution	Monthly mean temperature	Netcdf, Binary, Text	TDR (L1B) Swath data from 14 MSU/AMSU Microwave sounders	An error ensemble with 400 members. The error analysis includes sampling and diurnal adjustment errors.	
TOA Brightness Temperature 19V, 19H, 22V, 37V, 37H 85V, 85H (92 SSMIS)	1987- present	Swath data 50 km -14 km	3.8 – 1.9 seconds	Netcdf	TDR Swath data from 6 SSM/I and 1 SSM/IS	TBD	

Project Description

MSU/AMSU Air Temperatures and SSM/I, SSM/IS Brightness Temperatures



Production Approach – MSU–AMSU

■ Input Data:

- L1B Data from NOAA, NASA, and EUMETSAT instruments
 - 9 MSU Instruments (TIROS-N thru NOAA-14)
 - 5 AMSU instruments (NOAA-15, NOAA-18, NOAA-19, AQUA, METOP-A)

■ Processing Steps

- Raw brightness temperatures are adjusted for:
 - Local observation time (which drifts of time).
 - Satellite height and attitude. Satellite height changes over time.
- Monthly gridded maps are calculated and compared
- Inter-satellite differences are regressed to linear expression containing satellite offsets and target multipliers
- Adjusted data from different satellites combined together.

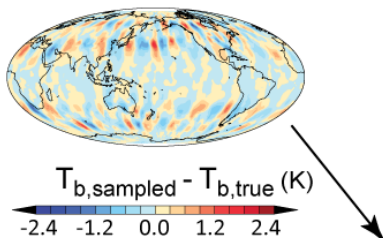
■ Documentation

ATBD and Documented Code in process of being transferred to NCDC

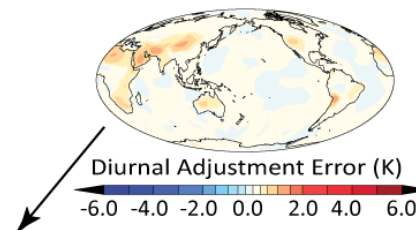
MSU-AMSU: Uncertainty Estimates

Monte-Carlo Method

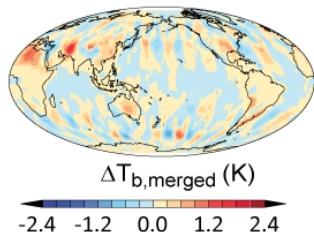
Take a series of instances of the estimated sampling uncertainty....



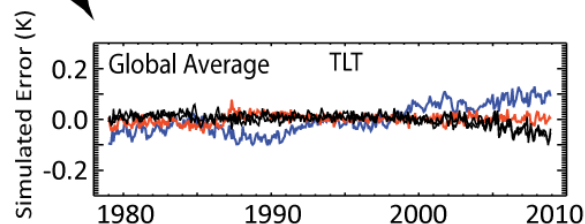
and an instance of the estimated uncertainty in each monthly diurnal adjustment....



...which are added together to make a combined uncertainty instance for each satellite and month. Uncertainty from each satellite are then combined into a single dataset using the same merging system as the actual measurements to obtain an instance of the estimated uncertainty.



Map of an instance of simulated errors for a single month.



Time series of 3 instances of the globally averaged errors. 400 such instances were generated in total.

Uncertainty realizations for all 4 MSU/AMSU products are available on our web site.

Production Approach SSM/I

- TDR are obtained from NRL (older) and CLASS
- TDR are reversed back to radiometer counts
- Radiometer counts are converted to antenna temperatures using standard 2-point + non-linear correction calibration equation. Two calibration points are hot load and cold load.
- Antenna temperatures are converted to brightness temperatures by applying the antenna pattern correction (spillover and cross-pol).
- Geolocation information is found: S/C nadir location, cell lat/lon, obs. azimuth and incidence angle, sun glint, percent land, possible ice.
- 13-bit quality flag is generated (missing data, thermistor, calibration or counts data oob, moon intrusion, etc.)
- Currently no precision or uncertainties are provided, but fixed NEDT values are known.
- Documentation:

User Manual: SSM/I V7 TB

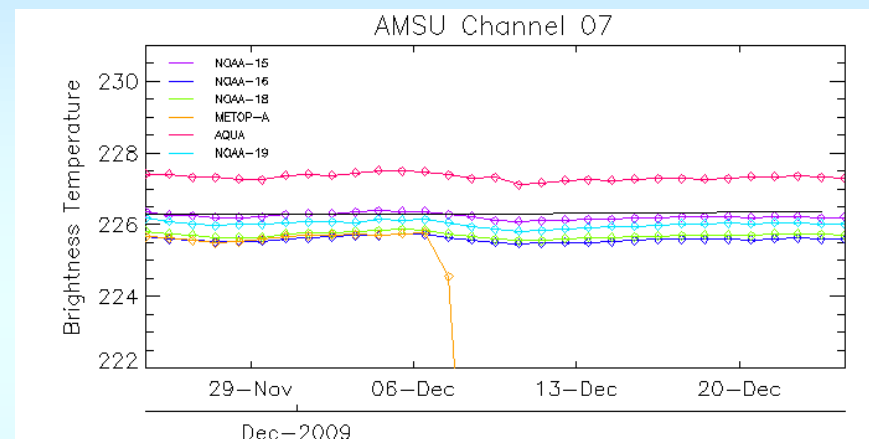
~~SSM/I V6 Calibration to be updated to V7 soon.~~



Quality Assurance Approach for MSU/AMSU

- Each observation is analyzed to make sure it is within reasonable bounds.

We monitor daily global averages of each channel and satellite. These are compared across satellites, and against long term means for the same data. This helps identify early signs of instrument failure – e.g. AMSU channel 7 on MetOP-A

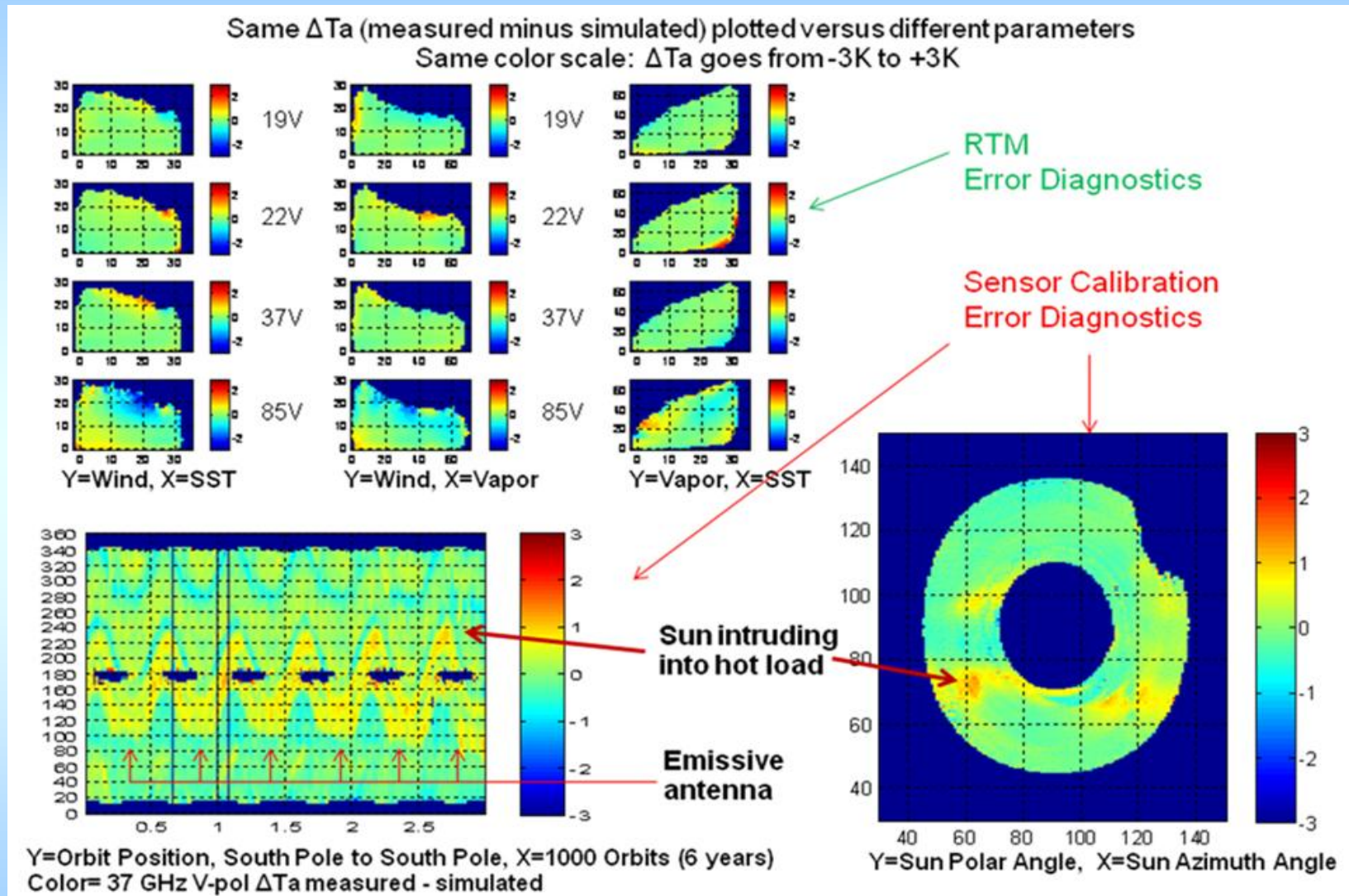


- We monitor monthly maps of number of valid data for each location. This helps identify data gaps for individual satellites.
- Visual evaluation of the monthly anomaly map for each AMSU channel can also help discover problems, e.g. RFI, missing data
- Comparison with other versions of the MSU/AMSU data, radiosonde data, and reanalysis output. This is done every several months and serves to evaluate longer term changes.

Quality Assurance Approach for SSM/I

- 25-year years of examining inter-calibration between satellites
 - Seven versions with careful inspection at each version change
- Consistency in all aspects of data processing
 - Start with sensor counts
 - Same calibration algorithm formulated in terms of physical contents that are sensor dependent.
 - Same geolocation algorithm that goes from S/C ephemeris to angles and locations. Precisely calibrated (1 km) base on imagery registration.
 - Same quality control and exclusions for all sensors
- Global, Mission-Life Analyses
 - Comparisons with radiative transfer model
 - Closure test: $T_b \rightarrow E_p \rightarrow RTM \rightarrow T_b$
 - Inter-satellite comparisons (SSM/I, TMI, WindSat, AMSR-E)
- Worldwide evaluation of EP coming from TB: 500 research papers, 7000 users (via NASA MEaSUREs Program).

Quality Assurance for SSM/I



Applications – MSU/AMSU

- Atmospheric Temperature is important for determining how much global warming has occurred in the past 3 decades.
- The MSU/AMSU data record is critical for assessing the long-term performance of Climate Models/GCMs
- Work is currently underway to evaluate CMIP-5 model performance.
- “Identifying Human Influences on Atmospheric Temperature: Are Results Robust to Uncertainties?”, Santer et al., submitted to the Proceedings of the National Academy of Sciences uses the RSS MSU/AMSU temperatures as well as the RSS uncertainty ensemble to evaluate results from 14 CMIP-5 models.
- Along with atmosphere temperature (MSU/AMS), winds, water vapor, and clouds (SSM/I, SSMIS) are essential climate variable required to answer the question: “How is the global earth system changing”.

Applications – SSM/I

Credit to NASA MEaSUREs Program

7,000 Users , 500 research papers

Mostly derived products, particularly Winds, rather than TB

Larger Projects Using Data

Higher Level Products	Data Set Producer	DISCOVER Data Used
NRL Storms Website	85 GHz Imagery of Storms	Brightness Temps
Multi-Decadal Sea Ice Climatology	Nat. Snow and Ice Data Center	Brightness Temps
GPCP	GSFC [Huffman et al, 2009]	Brightness Temps
GSSTF2b # *	GSFC [Chou et al, 2003]	Brightness Temps
Numerical Assimilation	GMAO	Brightness Temps
Direct Assimilation	EUMETSAT	Brightness Temps
Flux Products	Max-Plank Institute of Meteor.	Brightness Temps
Numerical Models	Remote Sensing Tech. Center of Japan	Brightness Temps
CCMP Ocean Winds #*	AER/NOAA AOML [Atlas, 2011]	winds
OAFlux	WHOI [Yu and Weller, 2007]	wind and vapor
LWP Climatology *	U Wisconsin [O'Dell et al, 2008]	cloud
Blended Sea Winds	NCDC, NOAA [Zhang et al, 2006]	winds
High Wind Atlas	U Hawaii [Sampe and Xie, 2007]	winds
Climatology of Global Ocean Winds	OSU [Risien and Chelton, 2006]	winds
Satellite Surface Turbulent Fluxes	Mark Bourassa, COAPS, FSU	winds

Climate Applications

- Microwave Imagers and Sounders are now providing:
 - Global atmospheric temperatures at 5 layers (1979 to present)
 - Ocean surface winds (1987 to present)
 - Total water vapor, cloud water, and rain rate over the oceans (1987 to present)
 - Through-clouds sea surface temperatures (1997 to present)
- The TBs are the fundamental basis for all the above.
- These multiple climate variables for MSU/AMSU and SSMI/SSMIS provide arguably the longest, most accurate picture of our changing climate over the last several decades.
- GCMs, assimilation models, climate models, in situ data sets all have deficiencies relative to precision satellite measurements.
 - Troposphere warming more slowly than predicted
 - Hydrological cycle in tropical Pacific is accelerating
 - Maybe due to climate oscillations, maybe not.
- As they grow in length and improve in accuracy, satellite climate data sets provide the most definitive picture of our changing climate.

Schedule & Issues

- Dataset and relevant documentation for MSU/AMSU is currently being transferred to operational status at NCDC.
- Entire V7 SSM/I TB dataset (1987-2011, F08 through F15) is completed and delivered to NCDC. Documentation and Software is being prepared and will be delivered end of year. User Manual now available.
- V7 TB calibration for AMSR-E, WindSat, and soon TMI are available via NASA funding
- FY2013 Proposal submitted for delivery of 2012 data and complete F17 SSM/IS.
- Concerns and How can the CDR Program better assist you?
 - Maintaining Precise Calibration Over Multiple Decades
 - Providing Users with Uncertainty Information
 - Funding Profiles: Maintaining excellence for ever growing datasets within a budget environment of decreasing funding is a serious challenge and quite stressful.
 - Limited Success in Demonstrating the Importance of these Datasets to Policy Makers.